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COMPARATIVE ANALYSIS OF M-QAM SIGNALINGS SCHEMES PERFORMANCE OVER FAST AND FREQUENCY NON-SELECTIVE RAYLEIGH FADING CHANNEL WITH MRC RECEIVER

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ABSTRACT

This paper presents a comparative analysis of some digital modulation signaling schemes over fast and frequency non selective Rayleigh fading channel with multiplicative distortion, Additive White Gaussian Noise (AWGN) and Maximal Ratio Combining (MRC) at the receiver. Three M-ary (with M = 4,8,16) modulation schemes, are used as the channel input and a comparative analysis is carried out in terms of Bit Error Rate (BER) averaged over the iterations (ABER) versus the Signal – to – Noise Ratio (SNR) for different orders of the M-ary modulation schemes using (MRC) technique at the receiver. Specifically, the propagation of the modulated waves over the channel and the processing of the received signal by an MRC were simulated using MATLAB 7.0 application package. The results show that, of the three modulation schemes considered, the ABER performance for 4- level quadrature amplitude modulated (QAM) signal is the best followed by that for 8QAM, while an excessive degradation is noticeable in the ABER performance of the 16QAM scheme when compared with the performances of the other two schemes even when an MRC receiver is used.

INTRODUCTION

The growing demands for voice, data and multimedia services in mobile communication systems have spurred advances in the wireless communication field in the last two decades. Digital modulation which allows data or digitized analogue information to be transmitted via analogue radio frequency (RF) channels is fast gaining ground as a potent technique for meeting these demands. Digital modulation techniques contribute to the evolution of wireless communications by increasing the capacity and speed as well as improving the quality of the mobile network. Mobile wireless communications progressed from Personal Communication Service /Network (PCS/PCN)) to Global System for Mobile (GSM) Radio Channel to General Packet Radio Service (GPRS) to Enhanced Data for Global Evolution (EDGE) to Universal Mobile Telecommunication Systems (UMTS) (better known as 3G) and will continue to evolve to 4G which is currently under active research (Wan Fariza, 2006).

Mobile communication is generally a complex process and a suitable channel model is needed to represent the effect of the propagation medium on the transmitted signal. One such model is that in which the modulated signal is assumed to propagate to the receiver over many different paths thereby resulting in multipath propagation. The main effects of the medium on the transmitted waveform result in the channel being classified as fast and frequency non selective with Rayleigh fading characteristics.

Mobile wireless systems operate under harsh and challenging conditions. The wireless channel is thus distinct and much more unpredictable than the wired channel due to factors such as multipath fading, shadow fading, Doppler spread and delay spread. Multipath itself is a phenomenon that occurs as a result of a transmitted signal being reflected by objects in the medium between the sender and a receiver. These reflecting objects may be buildings, trees, hills, vehicles, lampposts and human beings. The reflected signals arrive at the receiver with random phase angles, due to the different paths and directions taken by each signal to get to reach the receiver. The net result is a randomly time varying received signal which fades as the signals arriving at the receiver from the various paths combine constructively or destructively which effectively enhance or reduce the overall received signal energy for brief periods of time.

These factors all contribute to a fast and frequency non selective Rayleigh fading description of the channel (Bernard, 2003), which manifests in the variability of the received signal in a wide range of communication environments that may be encountered in practice. This variability can result in a noticeable degradation in the performance of mobile communication systems.

Various techniques have been developed to mitigate the effects of the propagation medium on the signal transmitted over wireless fading channels and thereby improve the performance of the communication system (Marvin et al., 2005). Maximal Ratio Combining (MRC) is one such technique used to reduce the resulting effects of multipath propagation on the received signal due to digital signal propagation over a Rayleigh fading channel.

In this paper, we present the results of using a Maximal Ratio Combining (MRC) technique to process the received signal from a fast and frequency non selective Rayleigh fading channel with AWGN and having an M-level (M=4,8,16) QAM signal at its input.

Specifically, the bit error rate (BER) average over the iterations (ABER) versus signal-to-noise ratio (SNR) performance is determined for each modulated input signal and the specified channel and receiver conditions. The results are then analysed and compared to determine the modulation scheme yielding the best results under the stated conditions

SIMULATION MODEL

Channel Model

Rayleigh fading is a multiplicative process whose simulation involves generating the multiplicative distortion factor, which is used to multiply the M-level (M=4, 8, 16) QAM signal for onward transmission to the receiver with an associated additive white gaussian noise as shown in Fig 2.1. Thus, the Rayleigh fading channel output is modelled generally as

$$r(t) = \sum_{i=1} h_i(t)\, s(t) + n_i(t) \quad \ldots\ldots\ldots\ldots (1)$$

where;

$r(t)$ is the overall signal at the receiver output N is the number of paths

$n(t)$ is the additive white gaussian noise (AWGN) at the receiver input

$s(t)$ is the transmitted signal from M –QAM (M=4,8,16)

h_i refers to a multiplicative distortion of the transmitted signal s(t) along the i^{th} path.

Fig. 2.1 represents the model for N = 2

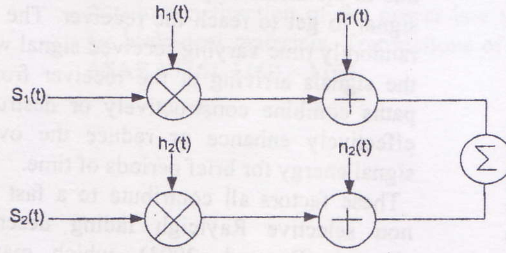

Figure 2.1; Multiplicative distortion and additive white Gaussian noise model for a fading channel assuming 2-transmission paths.

Assumptions

The assumptions of the model used for the simulation in this paper are as follows;

- the distribution of the fading follows a Rayleigh law since this models the mobile communication environment where there is no specular or direct path despite many indirect paths present due to obstructions.
- the noise is additive, white and Gaussian since there may be a large number of interfering signals from different sources which contribute to the modification of the transmitted signal.
- the MRC receiver is an integrate and dump filter, followed by a threshold detector. This is because the received signal needs to be integrated over one symbol period (the bit period) after which the output of the integrator resets to zero i.e. dump the integrator output at the end of a symbol period.
- the sampling interval is equal to one symbol interval T because a frequency non selective fading channel has been considered. Sampling interval greater than one symbol period will result in a frequency selective fading channel.
- 16 samples per symbol are used to avoid unduly long computation time
- the source data length is 10,000 bits so as to also avoid unnecessarily long computation time and because of the limitation imposed by the speed of the computer used which is an (Intel(R) Pentium(R) M processor, 1.70 GHz, 512 MB of RAM.)

Thus, Figure 2.2 represents the block diagram of the system model used for the simulation

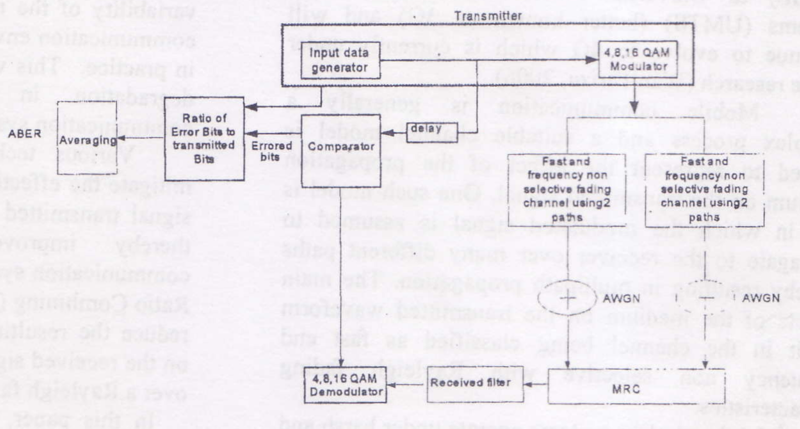

Figure 2.2 System Simulation model

METHODOLOGY

The received signals with two paths were then processed by a Maximal Ratio Combining (MRC) for different orders of QAM signaling schemes and the Bit Error Rate (BER) was determined for each of the modulated input signal which is the ratio of the number of bits incorrectly received to the total number of bits sent during a specified time interval. In a Maximal Ratio Combining receiver (MRC), multiple copies of the same information signal are combined so as to maximise the instantaneous Signal Noise Ratio (SNR) at the output. However, system designs often assume that the fading is independent across multiple channels and bit error rates over many iterations can be averaged. The flowchart for the simulation is shown in Fig. 3

Flow chart for the simulation study

The flow chart used for the simulation study based on the assumptions stated in Section 2.2 is as shown in Figure 3

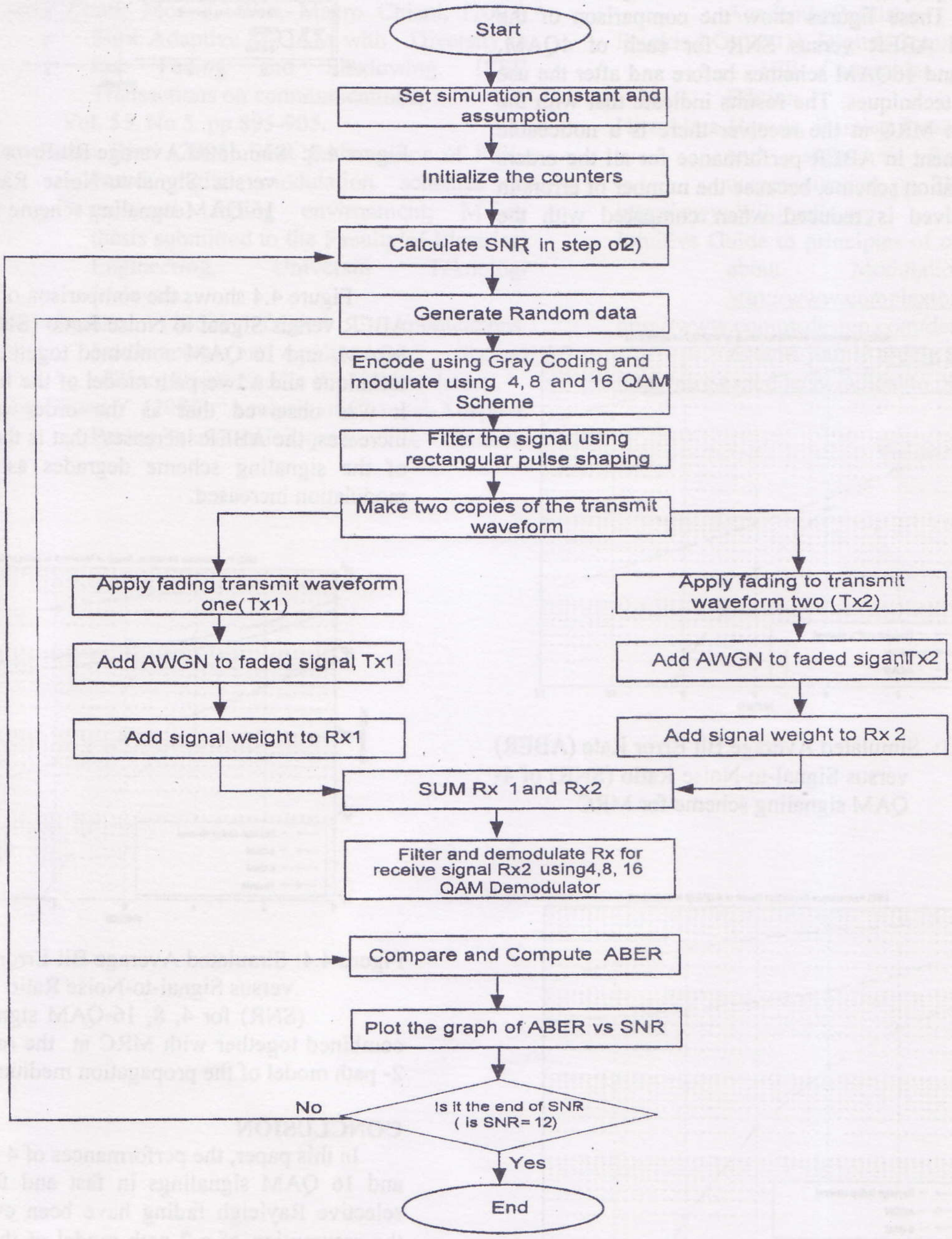

Figure 3: Flow chart for MATLAB Simulation

The simulation supports a randomly produced data to test the channel to impact on the BER performance under different signal constellations. After the source data is produced, the Gray encoder is used to map data to complex data which is applied to a 4QAM, 8QAM and 16QAM. The modulator output is in each case passed *through the fast and frequency non selective* Rayleigh fading channel with additive white Gaussian noise. The M-QAM demodulator processes the transmitted signals Tx1 and Tx2 to receive Rx1 and

Rx2 respectively. The received signals are added by an MRC and BER is determined at the output for value of SNR from 0 to 12dB, in steps of 2 dB.

RESULTS AND DISCUSSION

The simulation results which show the BER performances of 4QAM, 8QAM and 16QAM signaling schemes as a function of S/N ratio over fast and frequency non selective Rayleigh fading channel when a Maximal Ratio Combining technique is used at the receiver to reduce the variability resulting from multipath propagation are presented in Figures 4.1, 4.2 and 4.3. These figures show the comparison of the simulated ABER versus SNR for each of 4QAM, 8QAM, and 16QAM schemes before and after the use of MRC techniques. The results indicate that with the use of an MRC at the receiver there is a noticeable improvement in ABER performance for all the orders of modulation scheme, because the number of errors in bits received is reduced when compared with the situation.

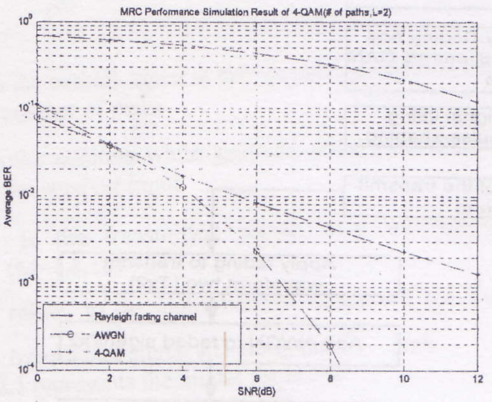

Figure 4.1: Simulated Average Bit Error Rate (ABER) versus Signal-to-Noise Ratio (SNR) of 4-QAM signaling scheme for MRC

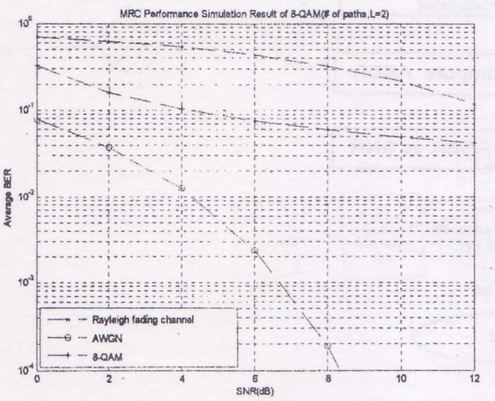

Figure 4.2: Simulated Average Bit Error Rate (ABER) versus Signal-to-Noise Ratio (SNR) of 8-QAM signaling schemes for MRC

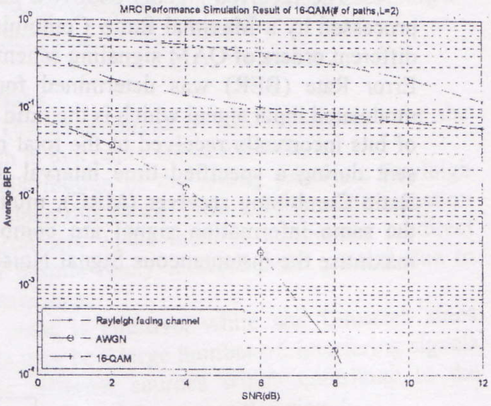

Figure 4.3: Simulated Average Bit Error Rate (ABER) versus Signal-to-Noise Ratio (SNR) of 16-QAM signaling scheme for MRC

Figure 4.4 shows the comparison of the simulated ABER versus Signal to Noise Ratio (SNR) of 4QAM, 8QAM, and 16 QAM combined together using MRC technique and a two-path model of the fading channel. It was observed that as the order of modulation increases, the ABER increases; that is the performance of the signaling scheme degrades as the order of modulation increased.

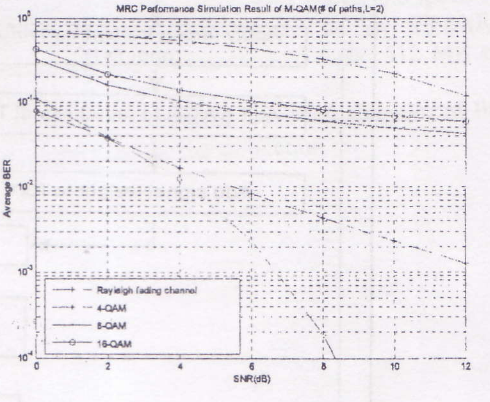

Figure 4.4: Simulated Average Bit Error Rate (ABER) versus Signal-to-Noise Ratio (SNR) for 4, 8, 16-QAM signaling schemes combined together with MRC at the receiver using a 2- path model of the propagation medium.

CONCLUSION

In this paper, the performances of 4 QAM, 8 QAM and 16 QAM signalings in fast and frequency non-selective Rayleigh fading have been evaluated under the assumption of a 2-path model of the transmission channel with multiplicative distortion and AWGN. The ABER performance of 4QAM signaling scheme was found to be lower than that of 8QAM and that of 16QAM signaling scheme. Therefore, the effects of multipath propagation on the performance of a mobile communication channel known to exhibit fast and frequency non selective fading behaviour are reduced using 4QAM modulation signaling with MRC. The simulation results show that the performances of these modulation schemes also depend on the order. The results presented here can be used by mobile network designers to mitigate the effects of fading, due to a fast frequency non selective fading characteristics of a channel, by making an appropriate choice of an appropriate modulation scheme at the sending end and an MRC receiver at the receiving end.

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